Recent Developments, Future Trends: Structural Analysis for Large Aperture Optics

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Some Preliminaries:

In the near future, precision, large aperture structures:

- Will be launched without the benefit of full component, system testing
- Will be configured, controlled, diagnosed without direct human interaction
- Will be driven to even greater extents by multidisciplinary effects (e.g. observational time, stability as functions of transient thermal radiation)
- Are likely to be subject to cryogenic effects that are not yet fully understood and analytically characterized
- Must be optimal; feasible designs probably will not be good enough

Some Preliminaries:

If we recognize state of the art needs to advance, we can:

- Do little, nothing
  - Hope commercial state-of-the-art advances independently
  - May actually not be an inexpensive option
- Work closely with commercial vendors
  - But which ones?
  - Directly-funded development often delivered as closed-source, licensed code
- Build high-level, other “connectivity” tools
  - Integration of moving targets (maintenance issues)
  - Limited access to underlying methods, opportunity for methods improvement
- Independently develop core, and system-wide, applications
  - Implies longest term commitment, clear “exit strategy” that fosters supplemental investment, assurance of technical advantage

Methods Development at JPL:

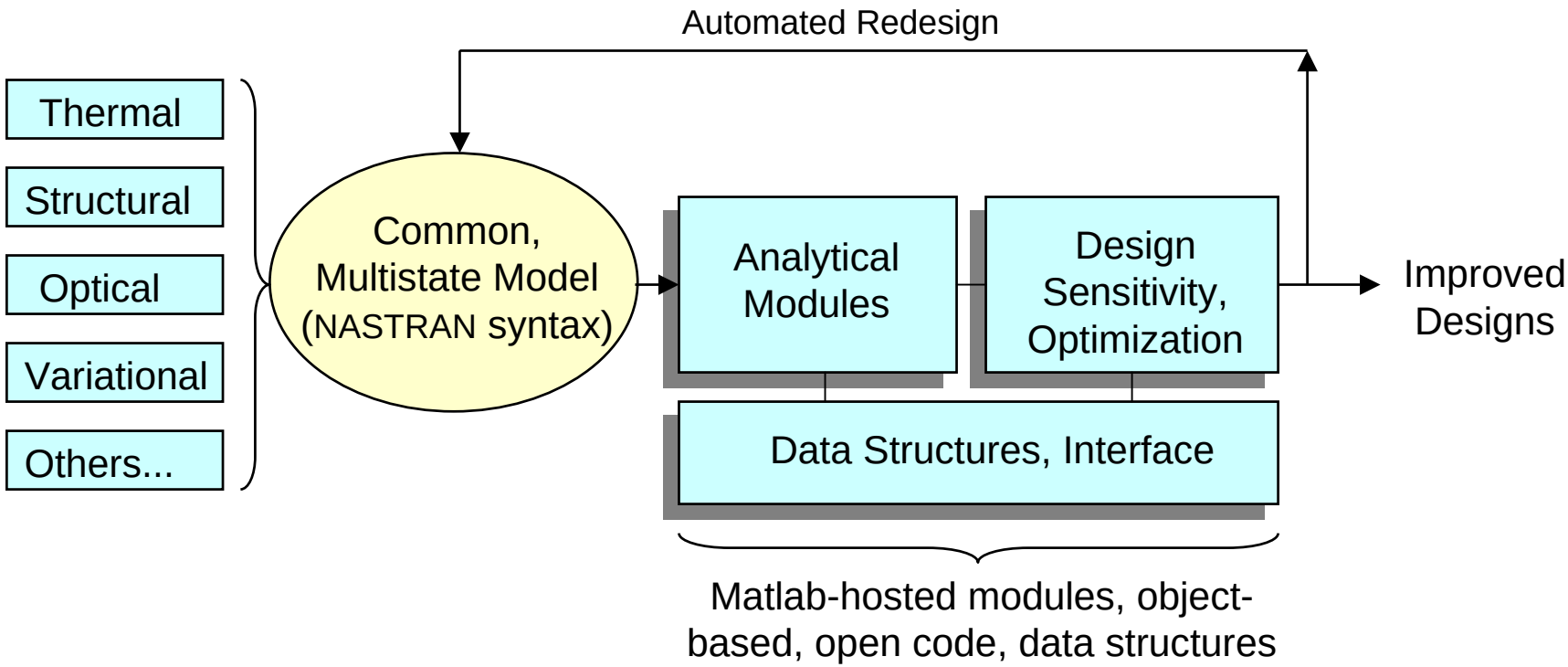
Integrated Modeling of Optical Systems (IMOS) has taken the independent approach. Development of entirely new analytic capability driven by:

- Extent of required technology advancement
- Unprecedented levels of required numerical precision, need for analytic "error budgets"
- Automated, multidisciplinary analytic capabilities that are not available commercially
- Point design knowledge alone not sufficient; need rational methods of design space exploration, automated improvement
- Necessity of having code that's open, extensible, and can take advantage of high-performance architectures (e.g. parallel systems)

New Analytical Environment:

Finite element-based capability for high-fidelity multidisciplinary analysis, design sensitivity, and optimization:

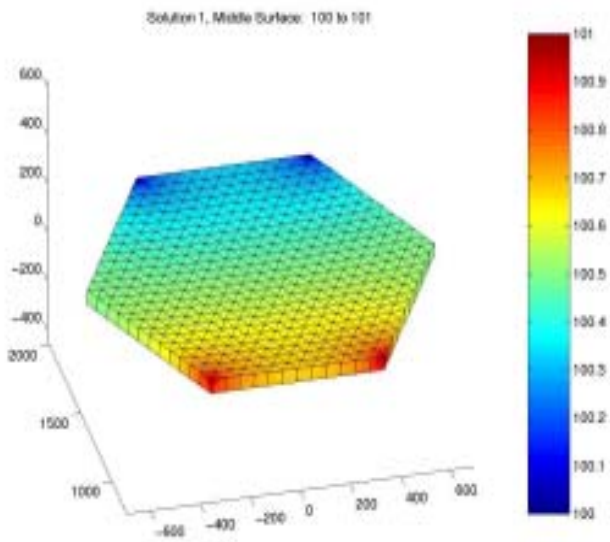
- Analysis is fundamentally integrated; models then are, by definition
- Open, extensible platform for collaborative methods development
- Still under construction, but architecture and much functionality already in place

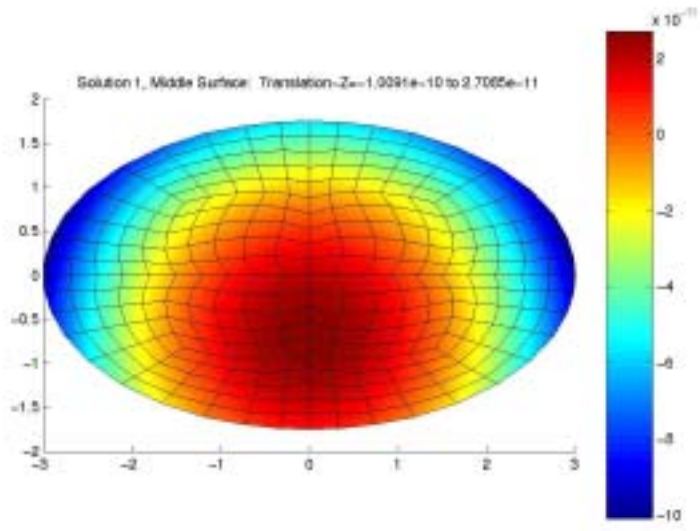


Current Analytical Capabilities:

Thermal, Structural Elements:

- Elements have both thermal, structural properties; single mesh for all analysis types
- Solutions can be coupled; grids have both thermal and structural degrees of freedom
- “Linear”, quadratic, cubic triangular and quadrilateral elements
- Point, edge, surface loads (fluxes, pressures, etc.)

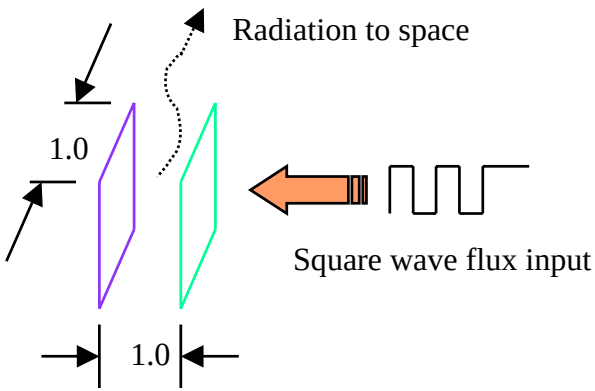


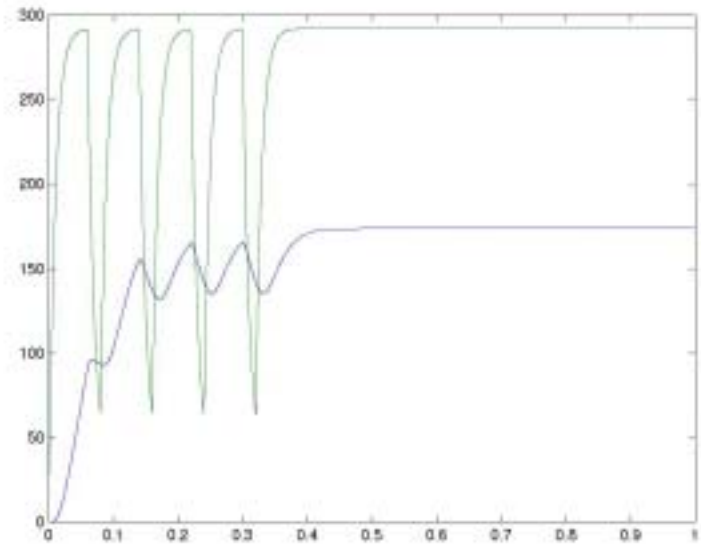


Current Analytical Capabilities (cont.):

Nonlinear Transient Heat Transfer Solutions:

- Matlab-hosted solutions feature:
  - Fixed/adaptive time stepping with bounds on time step, delta temperature
  - Full/modified Newton, adaptive tangent matrix update strategies, mixed implicit/explicit methods for radiation contribution.
  - Nonlinear iteration/convergence using temperature vector predictor with variable relaxation and L2 norms on residual and/or temperature correction vector



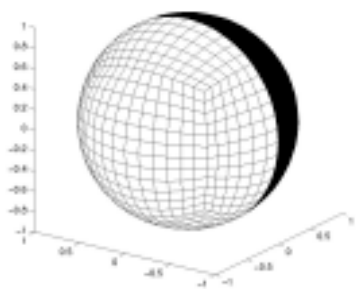


Current Analytical Capabilities (cont.):

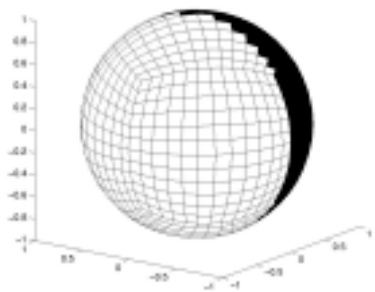
Nonlinear Heat Transfer Solutions, cont:

- Vehicle orbit positioning
  - Time-dependent loads from sun, planet(s) relative positions
- View factor calculation
  - Third-body shadowing, adaptive contour integration for highly-discretized models, very large number of exchange elements
  - Multicavity, with partial updates for time-dependent relative position changes
- Radiation matrix generation
  - Surface effects, exchange relationships expressed in finite element basis

$t_1,\ \theta = 0.$



$t_2,\ \theta = 45.$

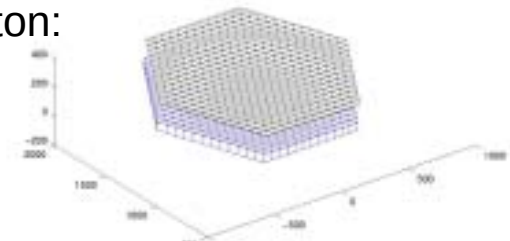


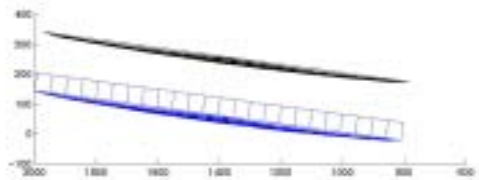
Current Analytical Capabilities (cont.):

Optical Modes Generation

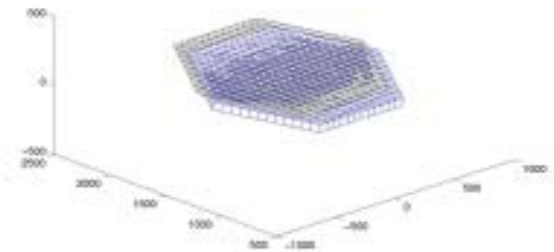
- Best-fit rigid body vector generation, projection, and automated optical element “partitioning” based entirely on Nastran input extensions
- To be used as a basis for Zernike, surface map generation for hand-off to optical analysis/design codes. (Can be seamless if Matlab-hosted.)

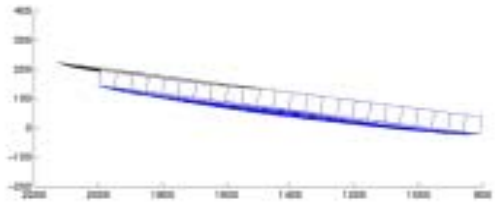
- Piston:





- Y-decenter:





Summary:

Open, integrated analytical capabilities under construction will offer:

- Extensible platform for knowledge capture and technology infusion to next-generation programs
- Efficient “point solutions” as well as fundamental, necessary capabilities for automated design synthesis and optimization
- Basis for fully exploiting recent advancements in computational hardware strategies

It is unlikely that the future of optimal, deployable, precision large aperture optics will be built entirely from closed-source, proprietary analytical components for structural analysis.